Monitoring of Arctic Conditions from a Virtual Constellation of Synthetic Aperture Radar Satellites

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LONG-TERM GOALS

Utilize a constellation of satellite radars to monitor the melting and freezing cycles of the Arctic Ocean north of 65^o. From difference maps of a timeseries of images deduce changes in ice extent, ice-type, and lead expansion/contraction with temporal resolutions from hours to days. Ultimately provide a routine Arctic coverage and generate products for operational purposes, and as validation, boundary conditions, and initialization to numerical ice-ocean forecast models.

OBJECTIVES

a) To create daily Arctic SAR images from the CSTARS SAR constellation.

b) To test and develop an appropriate ice-type classification technique from SAR attributes (e.g., backscatter) that distinguishes between new-, first-, and multi-year ice, and water, with focus on detection of the ice edge and leads.

c) To generate daily Arctic ice-type maps from the CSTARS SAR constellation using the ice-type classification technique mentioned in 2.

d) Comparison of ice-type products from multi-frequency, multi-polarization SAR sensors to gauge whether SARs can be combined, and if so, generate daily Arctic ice and ice-type maps with improved spatial coverage.

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e) Generation of difference images with temporal resolutions of hours to days between Arctic coverage and ice-type mosaics to illustrate changes in ice extent, ice edge, leads, and ice-types.

f) From amplitude and coherent change detection (ACD and CCD) images estimate global spatial rate of melting during the summer months and freezing during the winter months.

g) Monitoring of icebergs and breakage of glaciers and the speed of motion.

h) Monitoring of the Northwest Passage.

APPROACH

Arctic Coverage: CSTARS has access to numerous SAR satellites and will use them to monitor the arctic region like a constellation. We are collecting images to monitor the freezing cycle for the 2012 season in an area comprised of the Beaufort Sea, Chukchi Sea and Bering Sea. Use of multiple SARs provides the ability to image this Arctic region on a daily basis or even more frequently. Many of these SAR sensors have accumulated an extensive archive of historical data. For the above region we will select to acquire several interesting melting and freezing seasons to understand the rate of ice dissappearance and expansion. Figure 1 shows a typical coverage of the Arctic region on 5 November 2010 using the Cosmo-SkyMed-1 and Cosmo-SkyMed-2 satellites. Each satellite requires 15 passes and amounts to 200 images. In this example, Cosmo-SkyMed-3 and Cosmo-SkyMed-4 could fill in gaps easily near 80^{o} N. With this kind of coverage all snapshots would be merged to generate daily Arctic ice coverage mosaic. This example demonstrates that it is feasible to generate a daily Arctic Ice mosaic using two or more Cosmo-SkyMed satellites.

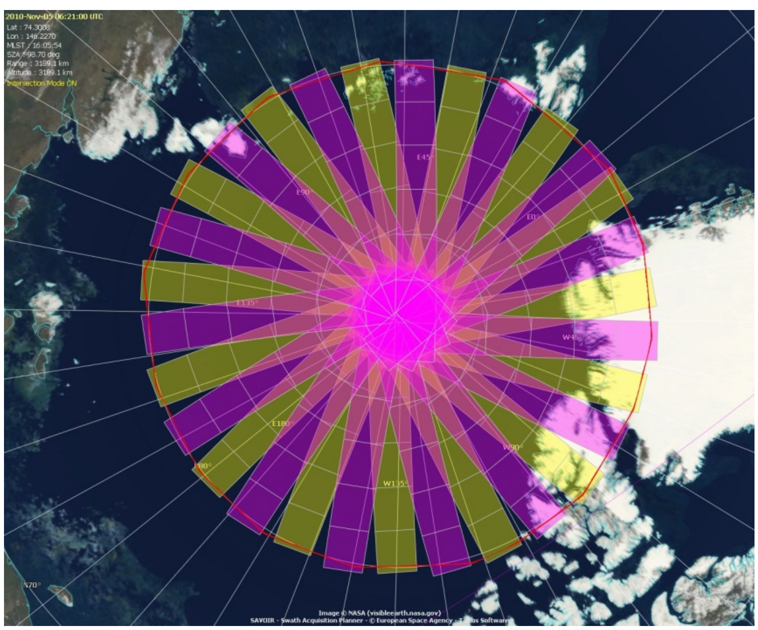

Figure 1: Arctic Daily Coverage on 5 November 2010 using CSTARS Constellation Satellites Cosmo-SkyMed 1 & 2 with HugeRegion Beam Mode.

Winter Ice Classifications: Obtaining a diverse collection of images, especially during the winter time freezing cycle will let us test and develop an appropriate ice-type classification technique from SAR attributes that distinguishes between ice-types and water, with focus on ice edge and lead detection. Amplitude change detection will be applied to ice-type images in order to monitor the changes in space and time. Since the classification algorithm will be based on first-order parameters, such as mean pixel backscatter and digital number several dual and quad polariztion images will be also acquired. From these multi polarized images polarimetric parameters can be derived such as co- and cross-polarization ratios (e.g., σhh/σvv, σhv/σvv), phase difference (e.g., σhh-σvv), and correlation coefficients (e.g., σhhvv/√σvvσhh).

Summer Ice Edge Determination:Although the variability of the surface ice conditions during the summer melt season leads to SAR signals that are very difficult to classify, the contrast of the backscatter from the open water and the ice surface is applied to determine the position of the ice edge. This is at a higher resolution than is possible using either passive microwave radiometry or visible reflection measurements, the latter being often rendered unusable because of the presence of low cloud in the marginal ice zone which is a common occurrence in the summertime Arctic. During the summer SAR imagery will be used to improve on the determination of the ice edge, and on the retrieval of ice concentration in the marginal ice zone. Figure 2 shows a Cosmo-SkyMed-2 image from 7 October 2010 @ 0943 UTC using HugeRegion (HR) beam mode (200 km swath & 100 m resolution) and VV polarization of the Arctic region near Greenland showing snow/ice covered land and icebergs drifting towards the open water. Open water and icebergs along the ice-water edge are visible as well as multi-year ice and types as seen by different scattering strengths (bright versus dark).

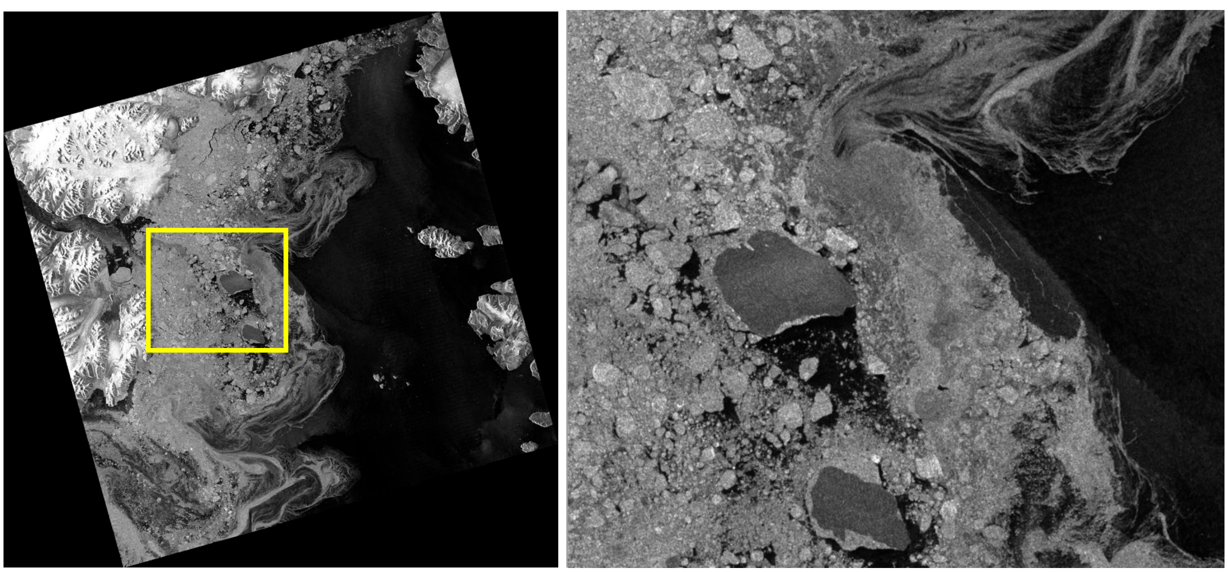

Figure 2: Left: Cosmo-SkyMed-2 Image from 7 October 2010 @ 0943 UTC using HugeRegion (HR) beam mode (200 km swath & 100 m resolution) and VV polarization. Right: Zoomed in look showing two larger icebergs as well as many smaller ones drifting towards the water's edge.

Ice Motion: Multiple amplitude SAR images anywhere from minutes to hours apart of the same region, but geo-referenced, will be used for amplitude change detection (ACD) products. Figure 7 shows two SAR images 18 minutes apart: CSK3 right-looking, ascending, beam WR_03 polarization VV on 03 September 2010 @ 08:50 UTC (red) and CSK2 right-looking, ascending, beam WR_04 polarization HH 03 September 2010 @ 09:08 UTC (cyan). The short time interval allows for perfect identification of the current pattern surrounding the larger iceberg which appears not moving due to blockage by rocks. The yellow arrows show a preliminary extraction of current pattern which shows an eddy to the north of the iceberg. Red pixels in the images show the original position of ice while cyan shows the new location which results a translation. Grey pixels indicate no change in position or orientation, i.e., no motion.

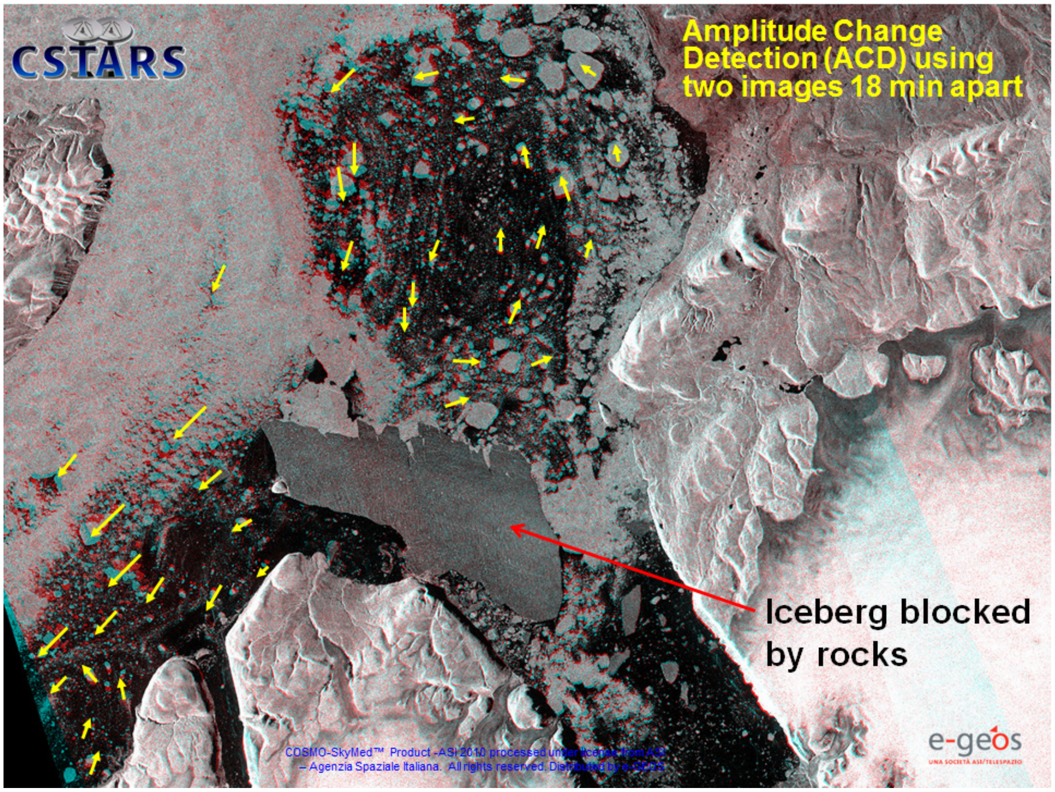

Figure 3: Two SAR images 18 minutes apart were used to generate this amplitude change detection image. CSK3 right-looking, ascending, beam WR_03 polarization VV on 03 September 2010 @ 08:50 UTC (red) and CSK2 right-looking, ascending, beam WR_04 polarization HH 03 September 2010 @ 09:08 UTC (cyan).

ACDs are derived from slightly different beam modes and different polarization while coherent change detection (CCD) images use the phase information from matching pairs of image with the same incidence angles and polarization along the same orbit. The Cosmo-SkyMed constellation of four satellites in the same orbit plane can provide CCDs within four days rather than the typical time of a repeat cycle.

WORK COMPLETED

Project just begun with collection of winter time freezing cycle.

RESULTS

Currently determination of the ice edge in the area of interest is defined with MODIS images and other data to schedule SAR collection along the advancing ice edge as freezing increases.

IMPACT/APPLICATIONS

The potential impact of the studies by this project is an improved algorithm of ice edge detection and ice type classification. Also the project will demonstrate that obtaining a daily mosaic covering the entire Arctic region is feasible with the constellation SAR satellites available to CSTARS.

RELATED PROJECTS

None